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Cost analysis of energy efficient solar water pumping system

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ABSTRACT

Increase in power demand leads to the distributed generation with renewable energy resources. Among different types of renewable energies, solar energy can be used for the production of adequate amount of power. In this work solar power panel simulation based on five parameter model with mono crystalline and poly crystalline panels is proposed for different solar radiation intensity and cell temperature. In addition photovoltaic water pumping system with the proposed model is analyzed towards the cost analysis. The performance analyses have been done with PV syst software.

Keywords: Solar energy, photovoltaic cell, photovoltaic module, PV syst software

1. INTRODUCTION

Renewable energy sources such as solar, wind, hydro and biomass energies are increasingly used to meet energy needs. The modeling of solar photovoltaic system is used to predict maximum power produced [1]. Hybrid PV systems offer improved proposition over PV-only systems [2, 11-13]. The technical and the commercial parameters were used to carry out the performance analysis of solar photovoltaic system installed [3]. Stand alone photovoltaic system is designed to operate residential appliances such as fluorescent lamp, incandescent light and ceiling fan. Total load is estimated and the array is sized to proper values in order to operate the estimated load reliably [4]. Set of match calculation methods are used for optimum sizing of PV/wind hybrid system. Here more accurate and practical mathematical models are used for characterizing PV module [5]. To overcome the lack of confidence due to the absence of reliability means for the development of the market of the hybrid systems, PV-wind hybrid system was developed [6, 7].

Modular systems are suited for cathode protection applications especially in remote and hilly terrains [8]. Flat roofs present a large potential of suitable areas for installation of PV plants. Flat roof PV installation has the advantage of being able to optimally positioned with support structures [9]. Many software used for the modeling of the solar photovoltaic system and to obtain the I-V and P-V curves and the performance of the system[10].Parameter calculation can be done by available analytical solution and numerical solution methods. Solar pumping project is an emerging technique which need control systems in surface water management. In this paper, a five parameter model of a poly crystalline solar panel is analyzed for different climatic conditions. A series parallel combination of 8×6 solar panels to match

with prescribed solar pump efficiency is analyzed and the cost analysis has been carried over for the specified solar photo voltaic water pump.

2. MODELLING OF FIVE PARAMETER PHOTOVOLTAIC SYSTEM MODELS

A photovoltaic system converts light into electrical direct current (DC) by taking advantage of the photoelectric effect. The current thus produced by this method is termed as photo current and it is denoted by I_{ph}. This photocurrent can be produced by any type of panel namely, mono crystalline solar panel, polycrystalline solar panel, hybrid solar panel or black solar panel. In this work a solar pumping system is analyzed for different operating conditions, a five panel model is selected and the best operating conditions for the solar panel and the solar pump are also proposed and the characteristics are studied for different working conditions the solar panel with polycrystalline structure is found to be more suitable for the solar pumping system.

Simulation Results of Five Parameter Modeling Using Mono Crystalline Structure

The five parameters calculated using the five parameter model are photocurrent, diode saturation current, diode thermal voltage, series resistance, shunt resistance.

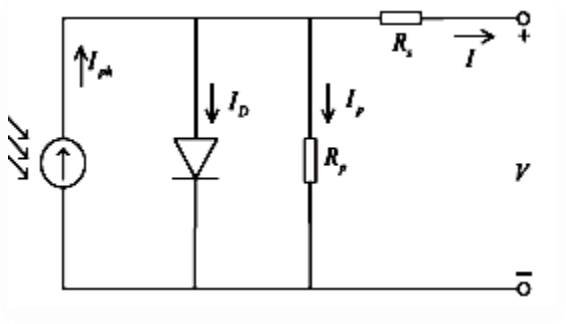

Fig-1.Five parameter model

The mathematical diode equation is given by,

$I=I_{ph}-I_D-I_p$ (1)

$I_D=I_0(e^{V+IR_s/Vt}-1)$ (2)

$I_p=(V+IRs)/R_P$ (3)

$I = I_{ph}- I_0 (e^{V+IR_s/Vt} - 1) - (V+IRs)/R_P$ (4)

Where,

I_{ph} – photo current (A), I_0 – Diode saturation current, V_t = Diode thermal voltage, R_s = Series resistance, R_P= Shunt resistance.

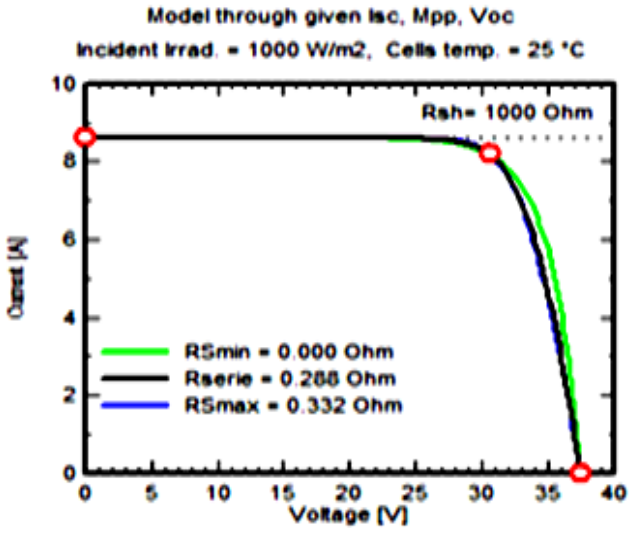

Fig-2. I-V characteristics for five parameter model with mono crystalline structure

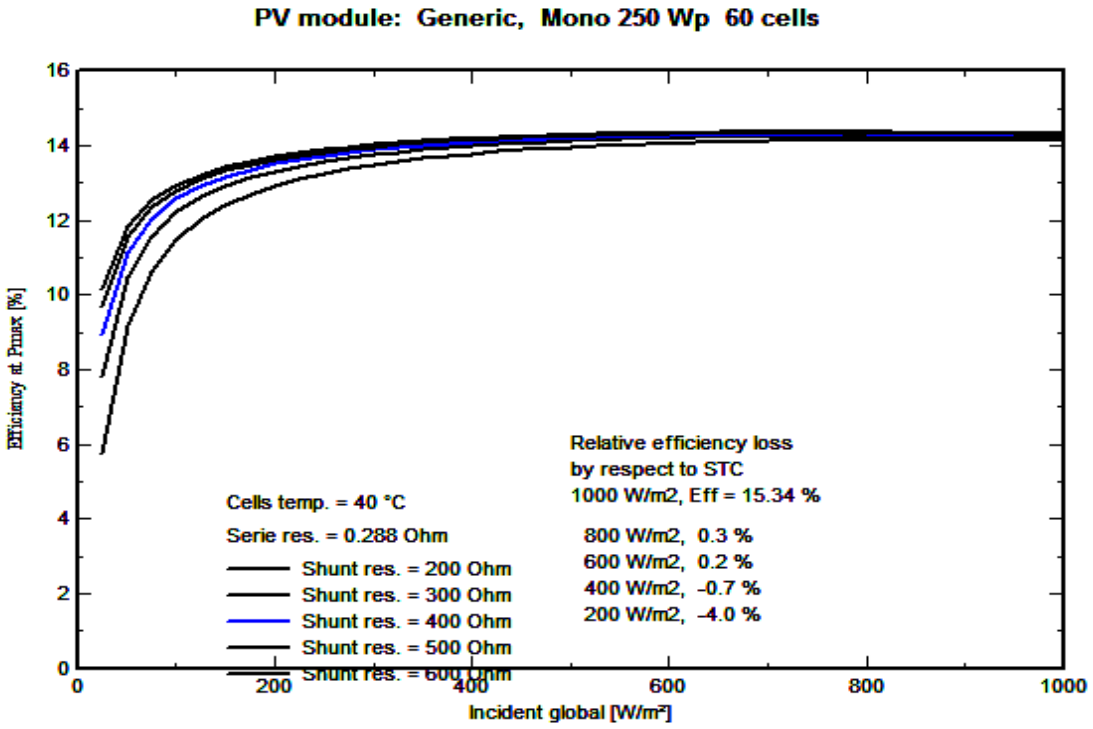

Fig-3.Efficiency curve for five parameter model with mono crystalline structure

Simulation Results of Five Parameter Modeling Using Poly Crystalline Structure

The curve will pass through three characteristic points namely, short circuit current, open circuit voltage and maximum power point. With the help of these points diode saturation current, quality factor and voltage temperature coefficient can be found out.

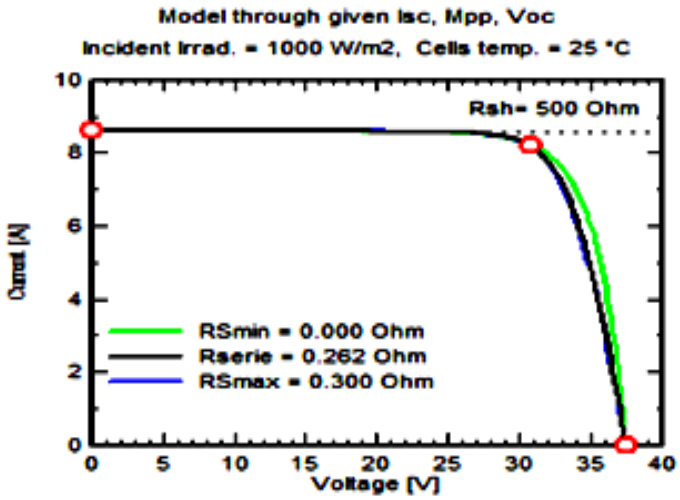

Fig-4. I-V characteristics for five parameter model with poly crystalline structure

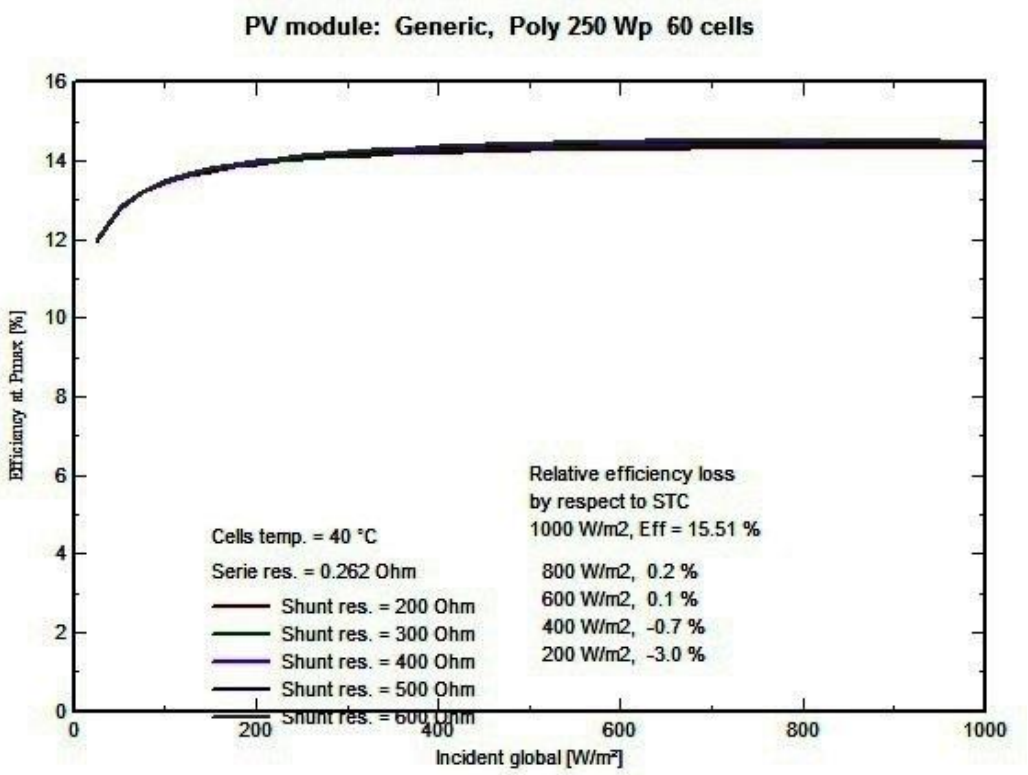

Fig-5. Efficiency curve for five parameter model with mono crystalline structure

3. ANALYSIS FOR PRODUCING MAXIMUM POWER

Maximum power can be produced by series parallel arrangement of the panels. The structure of 8 modules connected in series and 6 modules in parallel is given below.

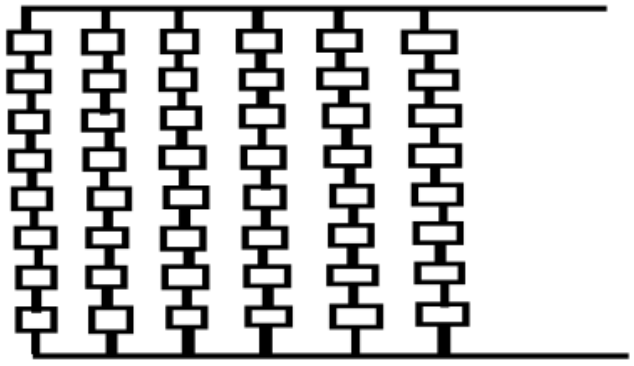

Fig-6. 8 modules in series and 6 modules in parallel.

Table 1: Comparison for five parameter model

PARAMETERS	MONO CRYSTALLINE	POLY CRYSTALLINE
I_{sc}	8.63A	8.63A
R_{sh}	1000 Ω	500 Ω
P_m	**250.2W**	**251.9W**
R_{se}	0.288 Ω	0.262Ω
H	**15.34%**	**15.51%**

V_{oc}	37.4 V	37.4V
V	31.3V	31.4V

Table 2: Evaluation of power produced

Irradiance=1000W/m² Module temp=32°c to 40°c			**Constant PMPP=12052to11991**					
Shading ratio	I-V	P-V	I-V	P-V	I-V	P-V	I-V	P-V
10%	43.4	43.4	43.4	43.4	43.4	43.4	43.4	43.4
20%	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3
30%	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4
40%	29.9	29.9	29.9	29.4	29.9	29.9	29.9	29.9

Here the shading ratio increases from 10 to 40% also temperature increases between 30 to 40° C. The resultant power is in between the 43.4 W to 29.8W and the maximum peak point power varies between 12052W to 11991W ~ 1.2Kw.

4. SOLAR WATER PUMPING SYSTEM

To match with 1.2 Kw solar panel a suitable solar pump has been analyzed. A PV powered water pumping system is similar to any other pumping system; only the power source is solar energy. Photovoltaic water pumping (PVWP) systems can meet a wide range of needs and are relatively simple, reliable, cost competitive, and low maintenance. The big advantages of solar pump are long term lower costs when compared with diesel or gasoline powered pumps. PV water pumpers do not require an on-site operator, and have a low environmental impact (no water, air, or noise pollution). Properly designed and installed PV water pumping systems are relatively simple to operate and maintain and can last decades. In this analysis, a 225w solar pump has been taken for consideration whose operating characteristics are given in table.3.

Table 3: Description of solar panel and solar pump

Solar panel	**Solar pump**
Poly crystalline panel	**Type of pump used**: DC pump
Number of array used:6×8 6 cells in parallel	**Power rating of the pump**: 225W
I_{sc}8.63A	**Running head (minimum):** 10.0 Meter watts **flow rate:** 0.553m^3/h **power:** 85W **efficiency**: 17.7%

Shunt resistance:500Ω	**Running head (Normal):** 60.0 Meter watts **Corresponding flowrate:**0.516m³/h **Corresponding power:**185W **Corresponding efficiency**:45.6%
Series resistance:0.262 Ω	**Running head (Maximum):** 80.0 Meter watts **Corresponding flowrate**:0.487 m³/h **Corresponding power:**225W **Corresponding efficiency:**47.2%
Efficiency:15.51%	**Efficiency**:17.7%to47.2%
Array nominal power:295Wp	**Pump power**:234W

5. OBSERVATION OF SOLAR PUMP WITH RESPECT TO SOLAR PANEL

Array nominal power : 295WP
Pump power : 234W

8 cells in series and 6 cells in parallel

With array nominal power 6×295 =1770W
: 1.7KW

According to shading ratio constant power varies from 12053W to 11991W.
The observations for different irradiation condition in an year is tabulated in Table 4.

Table 4: **Solar irradiation data /day**

MONTHS	INCIDENT KWh/m²day	PV avail KWh/day	PV needs KWh/day
Jan	5.8	1.6	1.7
Feb	6.6	1.8	1.7
March	7.0	1.9	1.7
April	6.9	1.9	1.7
May	6.3	1.8	1.7
June	5.8	1.6	1.7
July	5.3	1.5	1.7
Aug	5.2	1.4	1.7
Sep	5.5	1.5	1.7
Oct	6.1	1.7	1.7
Nov	5.8	1.6	1.7
Dec	5.5	1.5	1.7
Yearly average	6.0	1.7	1.7

6. SOLAR PUMP CHARACTERISTICS

The different observations of solar pump has been analyzed.

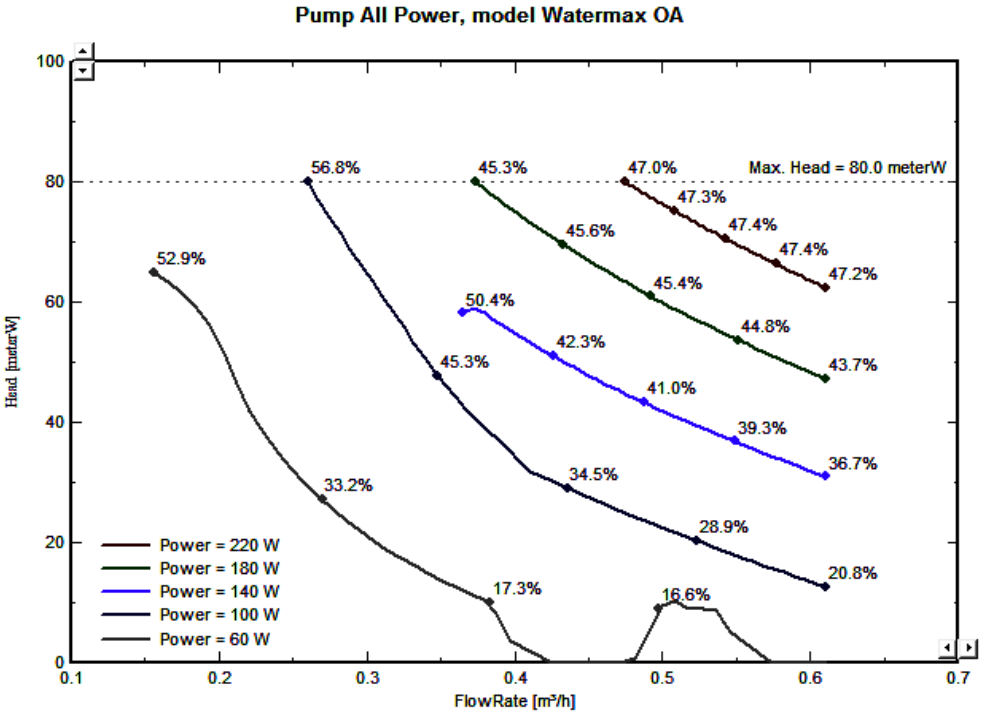

Fig 7. Head Vs flowrate

Figure 7 shows the power required for solar pump for different flow rates. When the power rating decreases from 220W to 180W then the flow rating will be decreased from 47.0% to 45.3%. For the power rating of 220W, 180W and the 100W the pump will in the normal operating condition. The maximum head level is 80.0 meter watts with the maximum power rating of 220W with the flow rate of 47.0%.From this figure it is identified that rating of 140W, 60W the pump will be in the under operating condition.

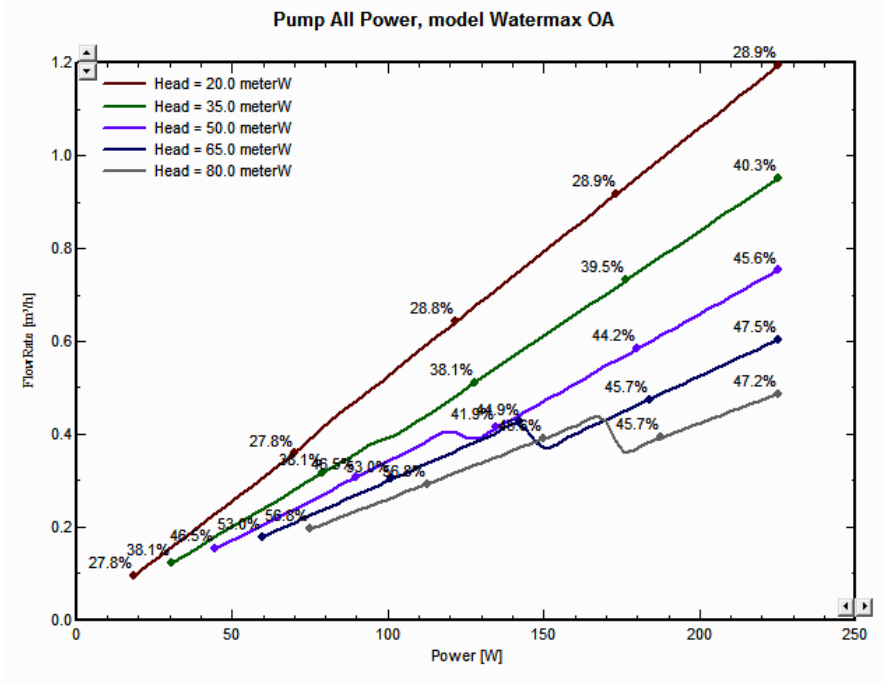

Fig.8. Flowrate Vs power

Figure 8 shows the flow rate Vs power for different head level of 20-80 Mw. For the head level of 20 meter w the flow rate will be 28.9% and it gradually reduces upto 27.8%.If the head level increases from 20.0meterW to 80.0 meter W then the flow rate will be decreased.

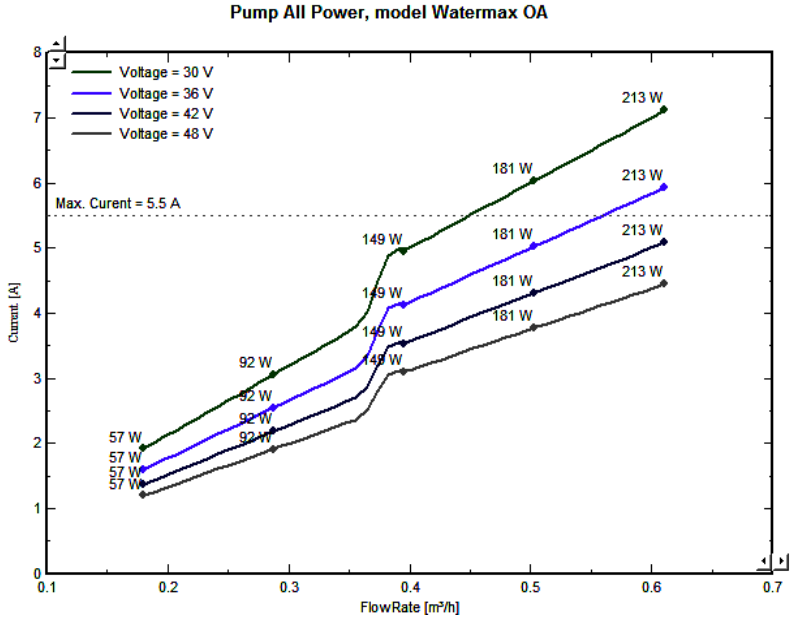

Fig.9.Current Vs flowrate

Figure 9 shows the current Vs flow rate for different voltages. As the current increases the flow rate will also be increased. Here the voltage increases from 30volt to 48volt for the maximum current of 5.5 amps. If the voltage rating is 30V then the power obtained for the corresponding voltage is 213W and 181W. If the voltage rating increases from 30V to 36V then the power obtained will be 213W. For the voltage rating of 30 V and the 36V the pump will be operating in the normal condition. If the voltage increases from 36V then it will be considered as under operating voltage.

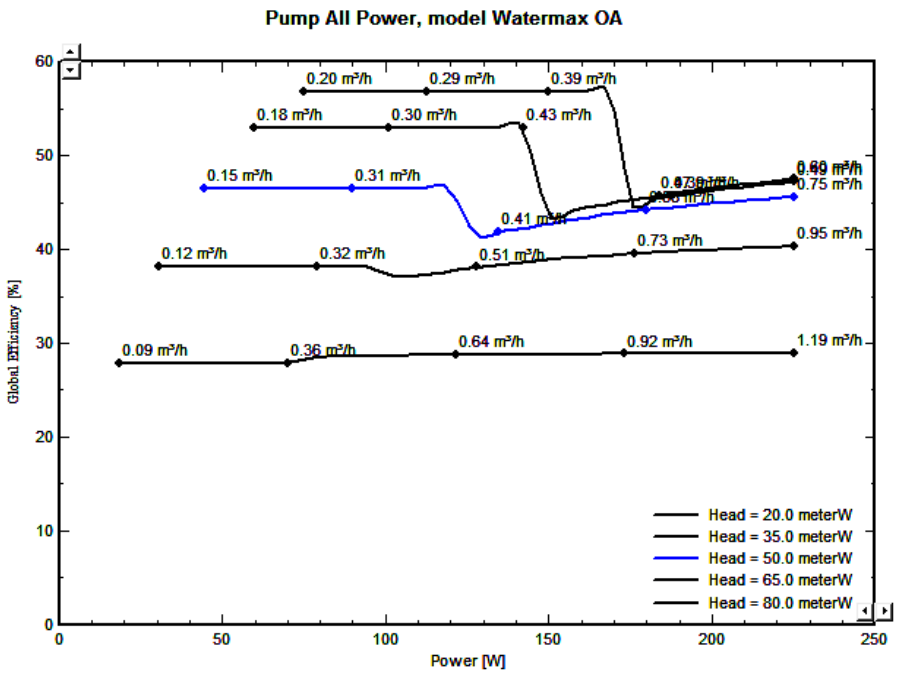

Fig.10. Power vs efficiency

Figure 10 shows the power Vs efficiency with different head levels. If the power increases the efficiency will also be increased. Here the head level increases from 20.0meterW to 80.0 meterW. With the increase in head level and the power rating the efficiency will also be increased. For the head level 20.0meterW the global efficiency will be27% and the flow rate will also be increased from 0.09to 1.19m^2/h and for the head level 35.0meterW, the global efficiency will be 38%.

7. COST ANALYSIS

The various industries producing solar panel and solar pumps is listed in Table 5 and Table 6.

Table 5: Cost analysis of polycrystalline solar panel

S. No	Product Name	Parameters	Cost
1	Alpex 250W	24Volt DC, I_{sc}=8.95A V_{oc}=37.25V,I_{mp}=8.35A V_{mp}=29.95V Warranty=25years	Rs 12,740
2	Sukam 250W	24Volt DC, I_{sc}=8.63A V_{oc}=30.72V, I_{mp}=8.14A V_{mp}=30.72V Warranty=25years	Rs 15,500
3	Trontek 250W	24Volt DC I_{sc}=8.87A ,V_{oc}=37.2V I_{mp}=8.3A,V_{mp}=30.1V Warranty=10years	Rs 12,750
4	Renesola 255W	24Volt DC I_{sc}=8.86A ,V_{oc}=37.50V I_{mp}=8.39AV_{mp}=30.40V Warranty=25years	Rs 12,450
5	MF energy solutions 250W	Solar panel of 250watts I_{sc}=8.33A , V_{oc}=37.8V I_{mp}=7.99A,V_{mp}=34.21V Warranty=25years	Rs 10,899

Table 6: Cost analysis of solar pump

S.no	Name	Product name	Parameters	Cost
1	Shurflo pumps	Solar water pumping kit for livestock watering and agricultural and horticultural projects	100foot dynamic head 1.5 GPM Kit mode:sp250-100 Estimated flow rate in summer=720Gallons/day (GPD) Estimated flow rate in winter=595Gallons/day (GPD) Maximum flow rate=1.5Gallons/minute (GPM) Solar panel rating=250watts	Rs.247,170
2	Singflo pumps	Solar water submersible pump	SCIN:3413076 Head=70Meter(230 feet) Flow rate=360liters/hour Inlet=50Mesh stainless steel screen	Rs.72,000 (24%off)

			Solar panel rating=200Watts Voltage=24volts Warranty=25years	
3	Gmx pumps	Centrifugal type with oil filled motor(0.4Hp)	SCIN=3014990 Type: dc pump Flow rate=24 Liters/hour for head level 56meters Flow rate=300 Liters/hour for head level 50meters Flow rate=3600 Liters/hour for head level 44meters Solar panel watts=400Watts Voltage=24volts	Rs.130.210 Structure cost=1000Rs/ Hp Installation cost=1000Rs/ Hp

8. CONCLUSION

This paper has presented the performance analysis of mono crystalline and polycrystalline panels for different solar radiation and cell temperature. The characteristics of five parameter polycrystalline model are found to be optimal. In addition, the same polycrystalline model is analyzed for high power production with series parallel combination. With the comparison, it is proved that the power produced by the polycrystalline panel is more than the mono crystalline panel. Also a solar pump characteristics matching with the power produced by the solar panel is analyzed. Further, a cost analysis for the polycrystalline panel and the solar water pump was analyzed. All the simulations were carried over through simulation in PVsyst software.

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Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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